Research Highlights

LBNL Heat Island Group

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White Roofs Cool the World, Offset CO_2 and Delay Global Warming

As the threat of global warming becomes widely recognized, scientists have proposed using geo-engineering (manipulation of the Earth's environment) to quickly respond to this threat. Most proposed geo-engineering techniques are novel and unproven. Two simple technologies that have been around for thousands of years, cool roofs and cool pavements, should be the first geo-engineering techniques used to combat global warming.

Increasing the solar reflectance of urban surfaces reduces their solar heat gain, lowers their temperatures, and decreases their outflow of thermal infrared radiation into the atmosphere. This process of "negative radiative forcing" counters global warming. In a recent study to be published in journal *Climatic Change*, Akbari, Menon and Rosenfeld have calculated the CO_2 offset, or equivalent reduction in CO_2 emission, achieved by increasing the solar reflectance of urban surfaces[1].

Most existing flat roofs are dark and reflect only 10 to 20% of sunlight. Resurfacing the roof with a cool white material that has a long-term solar reflectance of 0.60 or more increases its solar reflectance by at least 0.40. Akbari *et al.* estimate that so retrofitting 100 m^2 (1000 ft^2) of roof offsets 10 tonnes of CO_2 emission. Emitted CO_2 is currently traded in Europe at about $25/tonne, making this 10-tonne offset worth $250.

It is fairly easy to persuade (or to require) the owners of buildings to select white materials for flat roofs, and in California this has been required since 2005.[2] However, the demand for white *sloped* roofs is limited in North America, so California compromises by requiring only "cool colored" surfaces for sloped roofs. (This rule takes effect in July 2009.) Use of cool-colored surfaces increases solar reflectance by about 0.20 and yields a CO_2 offset of about five tonnes per 100 m^2, or about half that achieved with white surfaces. The solar reflectance of pavement can be raised on average by about 0.15, offsetting about four tonnes of CO_2 per 100 m^2.

Over 50% of the world population now lives in urban areas, and by 2040 that fraction is expected to reach 70%. Pavements and roofs comprise over 60% of urban surfaces (roofs 20 to 25%, pavements about 40%). Akbari *et al.* estimate that permanently retrofitting urban roofs and pavements in the tropical and temperate regions of the world with solar-reflective materials would offset 44 billion tonnes of emitted CO_2, worth $1.1 trillion at $25/tonne.

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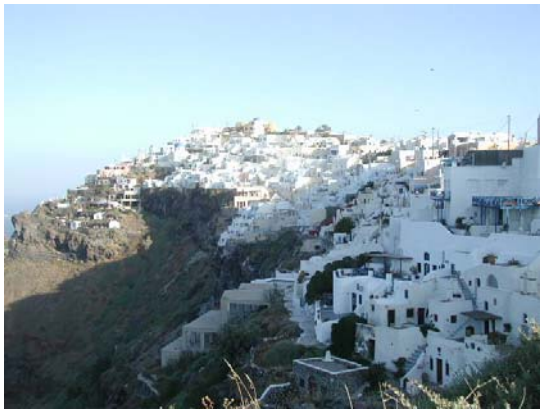
[1] Akbari, H., S. Menon, and A. Rosenfeld. 2008. "Global cooling: increasing solar reflectance of urban areas to offset CO_2," In press, *Climatic Change*. Hashem Akbari is a senior scientist (email H_Akbari@lbl.gov, phone +1-510-486-4287) and Surabi Menon (email SMenon@lbl.gov , phone +1-510-486-6752) is a scientist with the Lawrence Berkeley National Laboratory. Arthur Rosenfeld is a commissioner with the California Energy Commission (email Arosenfe@energy.state.ca.us, phone +1-916-654-4930).

[2] California has justified cool roofs based on cooling energy saving alone. White roofs save building's cooling-energy use by about 20% (and hence directly reduce CO_2 emissions from power plants). The estimated U.S. potential savings for white roofs are in excess of $1 billion per year in net annual energy bills (cooling-energy savings minus heating-energy penalties). Cool roofs also reduce the summertime urban temperatures leading to an improved urban air quality. The combined effect of the energy and air-quality savings from increasing the solar reflectance of urban surfaces in the U.S. alone can exceed $2 billion per year. For urban dwellers worldwide savings would be huge.

How can the reader visualize this *one time* offset of 44 billion tonnes of CO_2? If the average car emits 4 tonnes of CO_2 each year, permanently increasing the solar reflectance of urban roofs and pavements worldwide would offset 11 billion car-years of emission. This is equivalent to taking the world's billion cars off the road for 11 years. The offset provided by cooling urban surfaces affords us a significant delay in climate change during which we can take further measures to improve energy efficiency and sustainability.

Akbari *et al.* propose an international campaign to use solar reflective materials when roofs and pavements are initially built or resurfaced in temperate and tropical regions. They point out that such an international "cool cities" program is a win, win, win proposition. It is well known that cool roofs reduce cooling-energy use in air conditioned buildings and increase comfort in unconditioned buildings (win #1). The authors have also shown that cool roofs and cool pavements mitigate summer urban heat islands, improving outdoor air quality and comfort (win #2). Now, their latest research shows that cool roofs and cool pavements can cool the entire globe (win #3). Installing cool roofs and cool pavements in cities worldwide does not require delicate international negotiations about capping CO_2 emission rates. An international cool cities program can be used as a model to organize the world's efforts to mitigate global warming.



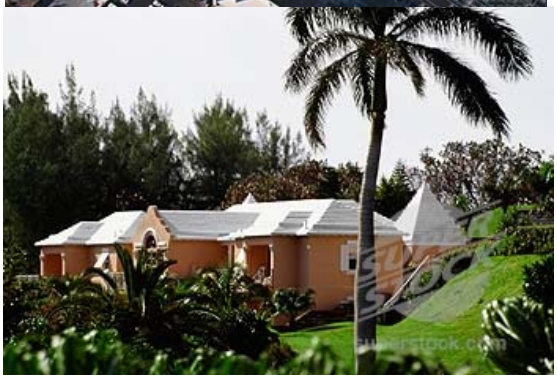


Figure 1. Cool roofs (clockwise, Bermuda, Dallas, and Santorini) offset CO_2 emissions and delay global warming. One hundred square meters (1000 ft^2) of a white roof, replacing a dark roof, offset the emission of 10 tonnes of CO_2.

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